WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 2

PHYSICS



EXAM QUESTION PACK

2.6 ELECTROSTATIC AND GRAVITATIONAL FIELDS OF FORCE

SCORE	PERCENTAGE
/109	%

STEMUP

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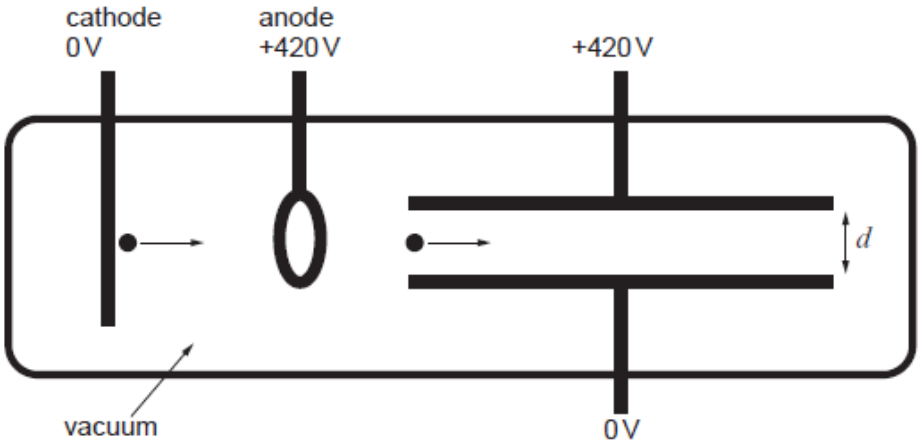
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#1

An electron is accelerated from rest by a pd of 420 V and then enters the uniform electric field between two parallel plates separated by a distance, d. These parallel plates also have a pd of 420 V across them and the electron enters halfway between the two plates.



(a) Show that, when the electron has travelled a distance, d, horizontally, it will have travelled a distance of $\frac{1}{4}d$ vertically (from the point where it enters the parallel plates). [5]

(b) Explain whether or not an oxygen ion with charge $-2e$ accelerated from rest in the above set-up instead of an electron would pass through the same point. [2]

Question taken from Eduqas examination paper 842103, November 2020

#2

2. *(a)* (i) Define the angular velocity, ω, for a body moving in a circle. [1]

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(ii) Two equations giving the acceleration of a body moving at constant speed in a circle are:

$$a = \frac{v^2}{r} \quad \text{and} \quad a = r\omega^2.$$

Show clearly that the equations are equivalent. [2]

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(b) A moon called *Deimos* orbits Mars in a circular path of radius 23 500 km. Astronomers have calculated the mass of Deimos to be 1.48×10^{15} kg, and the force exerted on it by Mars to be 1.15×10^{14} N.

(i) Calculate the speed of Deimos around Mars. [2]

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(ii) Explain whether or not a moon of twice the mass of Deimos, but in a circular orbit of the same radius about Mars, would have the same speed as Deimos. [2]

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Question taken from Eduqas examination paper 842101, June 2018

#3

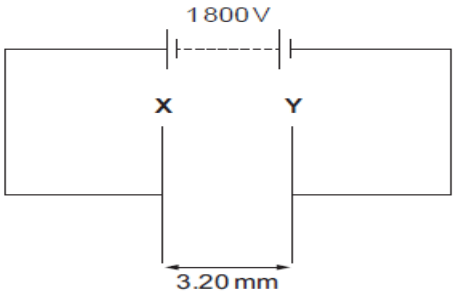
(a) A sphere made of caesium is placed in space and illuminated by ultraviolet radiation of photon energy 10.3 eV. The work function of caesium is 2.1 eV. Explain in clear steps, using Einstein's photoelectric equation (and other physics), why the maximum potential attainable by the caesium sphere is +8.2 V. [5]

(b) Hence, calculate the maximum electric field strength around the caesium sphere given that its radius is 6.5 cm. [3]

Question taken from Eduqas examination paper 842103, November 2020

#4

A scientist investigating electric fields places two parallel plates **X** and **Y** a distance 3.20 mm apart and connects them to a high voltage supply as shown. There is a vacuum between the plates.



(a) **Sketch the electric field pattern** between the plates indicating clearly the direction of the field. [1]

(b) Electrons are accelerated from plate **Y** to plate **X**. Calculate:

(i) the force on an electron; [2]

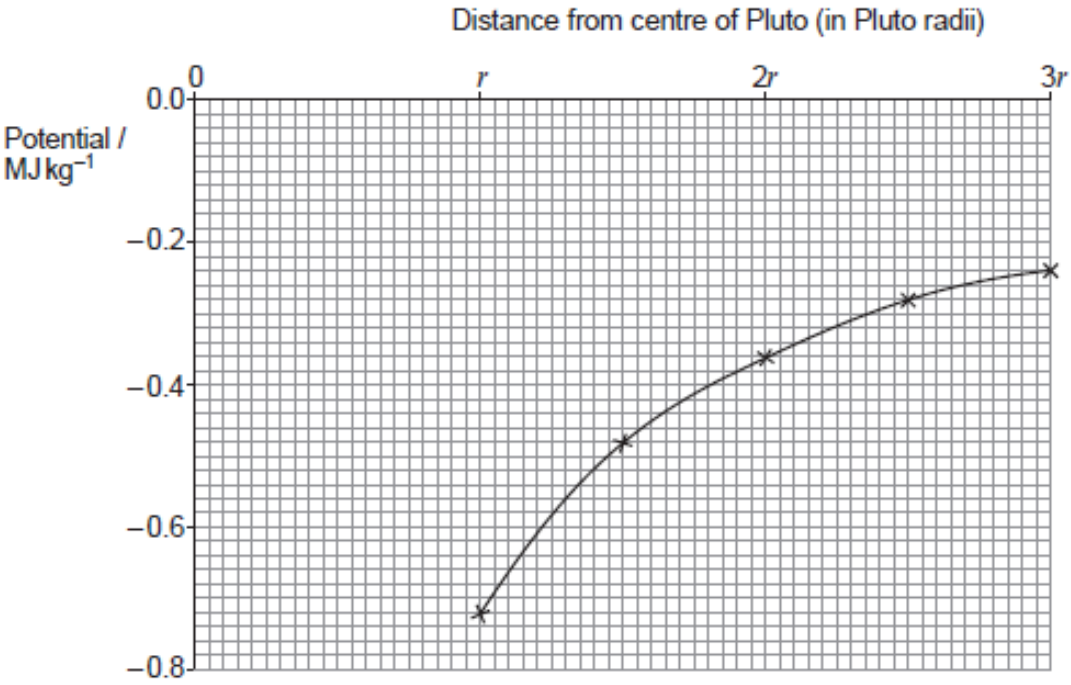
(ii) the gain in kinetic energy of an electron as it travels from **Y** to **X**; [2]

(iii) the time it takes for an electron to travel from **Y** to **X**. Assume the electron starts from rest at plate **Y**. [3]

(c) The separation between the plates is now halved but the pd is unchanged. The scientist believes that the gain in kinetic energy of an electron travelling (from rest) from **Y** to **X** will be unchanged. Verify this claim. [2]

Question taken from Eduqas examination paper 842102, June 2017

6. The variation in gravitational potential near Pluto is shown by the graph.



(a) Assuming that the potential at the surface is correct, confirm that the potential at $3r$ is plotted correctly. [2]

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(b) (i) Calculate the gravitational potential energy of a spacecraft of mass 600 kg at rest on the surface. [2]

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(ii) 'Escape velocity' is defined as the minimum velocity required for a body to escape from the gravitational influence of a massive body. Calculate the 'escape velocity' of the spacecraft. [3]

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(c) The radius of Pluto is 1.18×10^6 m and the gravitational field strength at the surface is $0.62\,\text{N kg}^{-1}$. Using this information and by **drawing a suitable tangent** show that the gravitational field strength at $2r$ agrees with the theoretical value given by:

$$g \propto \frac{1}{r^2}$$ [4]

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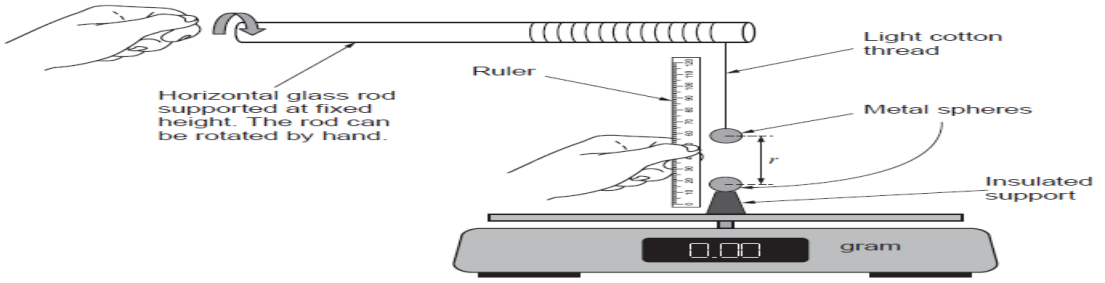
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Question taken from Eduqas examination paper 842102, June 2019

#6

Two students, Ben and Sarah, use the following apparatus to investigate the 'inverse square' nature of Coulomb's law.



The **same** negative charge is placed on both spheres. The distance, r, between the centres of the spheres is varied and the reading on the top pan balance is noted. Sarah and Ben disagree on the best method to measure r.

Ben favours using a ruler with a resolution of 1 mm to measure it directly.

Sarah suggests measuring the diameter of the glass rod with Vernier calipers, with a resolution of 0.01 mm, to determine the circumference of the rod. The rod can then be rotated by hand, with each complete rotation corresponding to the calculated circumference.

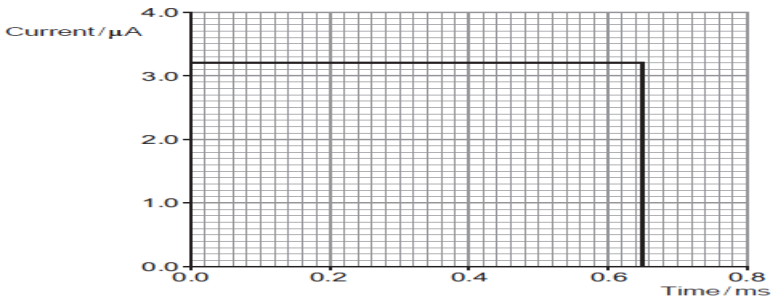
(a) (i) State an advantage and a disadvantage of each method. [4]

(ii) Suggest an improvement to **one** of the techniques which would increase the accuracy of measuring r. [1]

(b) When r = 20 mm, the reading on the top pan balance is 0.01 gram.

(i) Show that the value of Q_1Q_2, the product of the charges on the spheres, when r = 20 mm is approximately 4.4×10^{-18} C^2. [3]

(ii) One of the spheres is now discharged. The graph shows how the discharge current varies with time.



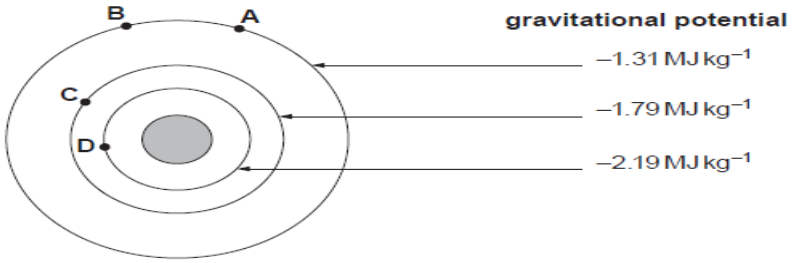
Show that the values given on the graph are consistent with the product Q_1Q_2 in *(b)*(i). [2]

(iii) Hence, estimate the number of electrons on **one** sphere when the reading on the balance is 0.01 gram and r = 20 mm. [1]

Question taken from Eduqas examination paper 842102, June 2017

#7

(a) The diagram shows a series of equipotentials around the Moon showing values of the gravitational potential. **A**, **B**, **C** and **D** are four points on the equipotentials.



(i) Explain why the potentials have negative signs. [2]

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(ii) A spacecraft of mass 300 kg orbits the Moon. Determine, showing your reasoning, the changes in the gravitational potential energy of the spacecraft when it moves from:

I. **A** to **B**; [2]

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II. **B** to **C**. [2]

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(iii) The spacecraft is now directed from point **D** towards the Moon's surface with an initial speed of $0\,m\,s^{-1}$ in this direction. Calculate the speed at which the spacecraft impacts with the Moon's surface.
[Mass of Moon = 7.35×10^{22} kg. Radius of Moon = 1740 km] [4]

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(b) Many space agencies have deliberately crashed their spacecraft on to the Moon for scientific purposes. The Lunar Crater Observation and Sensing Satellite (LCROSS) is one example which, along with its companion rocket, Centaur, impacted with the Moon in 2009. The following extract is taken from the space agency press release about the mission:

The primary goal of LCROSS is to measure the concentration of water (ice) in permanently shadowed lunar soil. When the Centaur, weighing up to 2366 kg hits the floor of a permanently shadowed crater there will be an initial flash followed by the creation of a debris plume. If water is present on the floor of the crater, it will be thrown skyward. The LCROSS spacecraft, following four minutes behind, will collect and transmit data back to Mission Control about the debris plume before itself impacting the surface. A possible result of both of the impacts is the creation of a temporary thin atmosphere of hydroxyl ions. This resulting atmosphere could be detectable using telescopes on Earth.

[NASA LCROSS press kit June 2009]

Discuss the benefits and cost to society of such missions. [2]

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Question taken from Eduqas examination paper 842102, June 2017

#8

8. *(a)* State **one** similarity and **one** difference between gravitational and electric fields. [2]

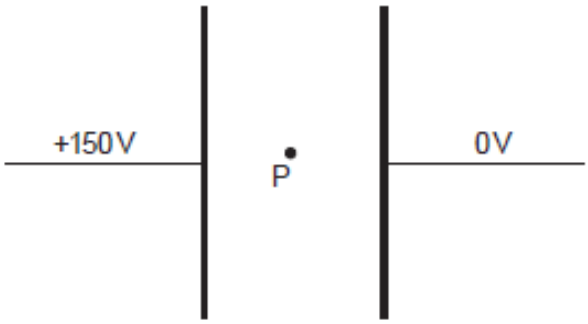
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(b) Two parallel vertical metal plates are placed 5.0 cm apart in a vacuum as shown. A pd of 150 V is placed across the plates and a small sphere of mass 9.6×10^{-15} kg carrying a charge of -2.4×10^{-17} C is placed at point P. A side-on view of the arrangement is shown.



(i) Show that the two forces acting on the sphere are approximately 9×10^{-14} N vertically and 7×10^{-14} N horizontally. [3]

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(ii) Draw, in the space below, a free body diagram for the sphere, showing the magnitude and direction of the two forces acting on it. Determine the direction with which the sphere will move away from P and include this on your diagram. [3]

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(c) Calculate the time taken for the sphere to travel a distance of 2.0 cm. [4]

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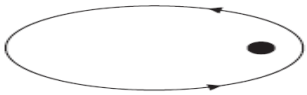
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Question taken from Eduqas examination paper 842102, June 2019

#9

(a) The diagram shows the elliptical orbit of a planet around a star. Use the diagram (by adding to it) to explain Kepler's second law of planetary motion. [2]



(b) Starting with Newton's law of gravitation, show that for a circular orbit, the period of orbit, T, of a planet around a star is related to its distance, r, from the centre of the star by the relationship $T^2 \propto r^3$. [Assume the mass of the planet is much less than the mass of the star.] [3]

(c) Mars has two small moons, Phobos and Deimos. The diagram shows their orbital paths around Mars.



(i) Phobos has an orbital period of 7.7 hours and the radius of its orbit is 9400 km. Show that the mass of Mars is approximately 6.4×10^{23} kg. [3]

(ii) It is proposed to send a space-probe to study Phobos and Deimos. The first part of the mission will be to place the probe in orbit around Phobos.

I. Show that the gravitational potential due to Mars at the Phobos orbit is approximately $-4.5\,\text{MJ kg}^{-1}$. [2]

II. The second part of the mission involves manoeuvring the space-probe into a higher orbit to enable it to study Deimos. However, on the journey to Mars the probe used more fuel than was expected. Scientists are now unsure as to whether or not the probe has enough fuel to enable it to reach the orbit of Deimos. The following information is available:

Energy available per kg of space-probe: $4.4\,\text{MJ kg}^{-1}$
Efficiency of fuel-burn process: 60 %
Distance of Deimos from centre of Mars: 23 500 km

Assuming the mass of the fuel is very small compared to the mass of the probe itself, and ignoring the gravitational effects of both moons, determine whether or not the scientists should attempt the manoeuvre. [4]

(iii) Explain why it is not possible to use the equation $\Delta E_p = mg\Delta h$ when determining the change in the gravitational potential energy of the probe as it moves between these orbits. [1]

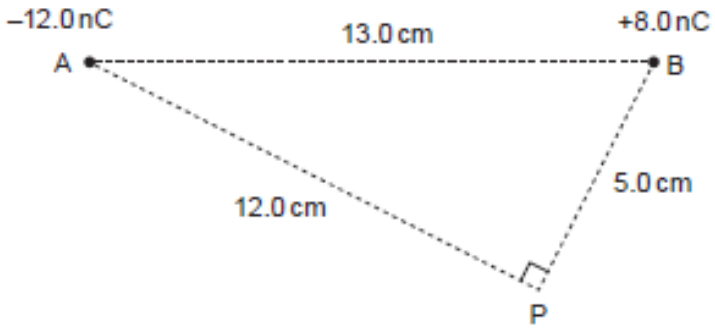
Question taken from Eduqas examination paper 842102, November 2020

#10

7. *(a)* Complete the following table: [3]

Quantity	Definition	Vector or Scalar
Electric field strength, E	.....	.....
Electric potential, V	.....	.....

(b) Point charges of –12.0 nC and +8.0 nC are placed at A and B, 13.0 cm apart as shown. P is a point in space which is 12.0 cm from A and 5.0 cm from B.



(i) Draw on the diagram **two** arrows to show the directions of the field strength at P due to each charge. [1]

(ii) Hence draw on the diagram **one** arrow to represent the direction of the resultant field strength at P. **Label this arrow R.** [1]

(iii) Calculate the **magnitude and direction** of the electric field strength at P. [4]

(c) (i) Show that the potential at P is + 540 V. [2]

(ii) Calculate the gain in kinetic energy in joules of an electron as it moves from infinity to P. [2]

(d) Without calculation, explain how the de Broglie wavelength of the electron changes as it moves towards P. [3]

Question taken from Eduqas examination paper 842102, June 2018

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		$\frac{1}{2}mv^2 = eV$ applied (1) $d = vt$ used (1) $s = \frac{1}{2}at^2$ used for vertical motion (1) $a = \frac{Vq}{md}$ (1) Substitutions & ok algebra (1)	1	1 1 1 1		5	5	
	(b)		Both are -ve charges **OR** move same direction (1) Independent of m and q, hence, yes (1)			2	2		
			Question total	**1**	**4**	**2**	**7**	**5**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	$\omega = \frac{\text{angle swept out}}{\text{time taken}}$ [or in words] Or angle [accept: number of radians] swept out per unit time [or per second]	1			1		
		(ii)	Clear use of $\omega = \frac{v}{r}$ or equivalent (1) Convincing algebra (1)	1	1		2	1	
	(b)	(i)	Substitution into: $F = m\frac{v^2}{r}$ or equivalent either before or after rearrangement (1) v = 1.35 km s^{-1} (1)	1	1		2	1	
		(ii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ or equivalent with M and m correctly identified (1) m cancels so speed of moon of twice the mass would be the same as that of Deimos. [Must be supported by argument even if argument not clear enough to give first mark.] (1) or in words, e.g. Equivalence of gravitational and inertial mass however expressed, [e.g. the force would be double and the mass is doubled] (1) Hence speed the same (1) or Another identical moon next to the existing one will orbit at the same speed (1), so the composite moon [of double the mass] will orbit at that speed (1).		2		2		
			Question 2 total	**3**	**4**	**0**	**7**	**2**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		2.1 eV required to free electron **OR** subbing into Einstein's (1) Remainder (8.2 eV) can become KE (1) 8.2 V corresponds to 8.2 eV (for electrons) (1) +ve will stop electrons from escaping (or attractive force) (1) Hence, +8.2 V is just enough to stop any electrons escaping (or any greater and the electrons can't escape etc.) (1)	1 1	1 1 1		5		
	(b)		$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ quoted **OR** used **OR** implied (1) Hence, $E = \frac{V}{r}$ **OR** Q obtained using V equation (59.3 pC) (1) Answer = 126 [V m^{-1}] **OR** 1.26 if [V cm^{-1}] (1)	1	1 1		3	2	
			Question total	**3**	**5**	**0**	**8**	**2**	**0**

#4

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
	(a)		Horizontal line[s] with direction indicated from X to Y	1			1		
	(b)	(i)	Substitution into $F = \frac{Ve}{d}$ shown: $\frac{1800 \times 1.6 \times 10^{-19}}{3.2 \times 10^{-3}}$ (1) $F = 9.0 \times 10^{-14}$ [N] (1)	1	1		2	2	
		(ii)	[Gain in E_k = Work done by field] Gain in $E_k = 9.0 \times 10^{-14} \times 3.2 \times 10^{-3}$ (1) (**ecf** on F) Gain in $E_k = 2.88 \times 10^{-16}$ J **unit mark** (1) **Alternative:** $W = 1.6 \times 10^{-19} \times 1800$ (1) $W = 2.88 \times 10^{-16}$ J **unit mark** (1) [Accept 1 800 eV **unit mark**]	1	1		2	2	
		(iii)	$x = ut + \frac{1}{2}at^2$ and $u = 0$ (all possible by implication) (1) $a = \frac{F}{m}$ **and** substitution step: **ecf** on F e.g. $t^2 = \frac{2 \times 3.2 \times 10^{-3} \times 9.11 \times 10^{-31}}{9.0 \times 10^{-14}}$ (1) $t = 2.54 \times 10^{-10}$ [s] (1) **Alternative:** $\frac{1}{2}mv^2 = 2.88 \times 10^{-16}$ to calculate v (1) Application of $x = \frac{(u+v)t}{2}$ (1) **ecf** on v $t = 2.54 \times 10^{-10}$ [s] (1)	1	1 1		3	3	
	(c)		F doubled (explained from $\frac{Ve}{\frac{1}{2}d}$) (1) $W = 2F \times \frac{d}{2}$ so no change (1) **Accept:** $W = QV$ and Q stated to be constant (1) so W remains unchanged (1)			2	2		
			Question total	**4**	**4**	**2**	**10**	**7**	**0**

#5

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
6	(a)		$V \propto \frac{1}{r}$ or equivalent or $\frac{-0.72 \times 10^6}{3}$ seen (accept 0.73) [1] V shown as -0.24×10^6 [J kg^{-1}] [1] Accept answers based on determination of			2	2	1	
	(b)	(i)	Substitution: $E_P = 600 \times [-] 0.72 \times 10^6$ [1] $E_P = [-] 4.3 \times 10^8$ [J] [1]	1	1		2	1	
		(ii)	Concept: $E_k = -E_P$ or equivalent [1] Substitution: 4.3×10^8 **ecf** $= \frac{1}{2} \times 600 \times v^2$ or $v = \sqrt{2 \times 0.72 \times 10^6}$ [1] $v = 1.2$ k[m s^{-1}] [1]		3		3	2	
	(c)		Equation used to show that g at $2r$ should be ¼ of surface value or determined i.e. g at $2r = 0.15(5)$ N kg^{-1} or $gr^2 = k$ or equation used to calculate mass of Pluto [1] Good tangent [1] Gradient calculated e.g. $\frac{0.56 \times 10^6}{3 \times 1.18 \times 10^6} = 0.15[8]$ (approx.) [1] Appropriate comment or analysis to show that $g \propto \frac{1}{r^2}$ [1]			4	4	3	
			Question 6 total	**1**	**4**	**6**	**11**	**7**	**0**

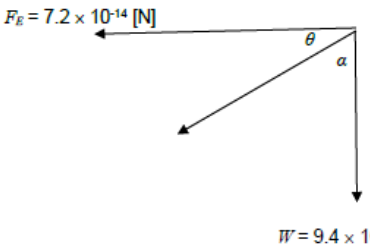
#6

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	<table><tr><th></th><th>Advantage</th><th>Disadvantage</th></tr><tr><td>Ben (ruler)</td><td>Easy to use/convenient / quicker</td><td>Inaccurate [only to ± 1 mm] / reference to parallax errors / difficulty in supporting ruler / may touch spheres</td></tr><tr><td>Sarah (rod)</td><td>Diameter measured accurately / greater accuracy</td><td>Diameter/radius of spheres need to be known beforehand / difficult to judge one complete rotation / difficult to measure angle [of rotation] / difficult to set-up / thread overlapping</td></tr></table> 4 × 1 mark - one response required from each cell.		4		4		4
		(ii)	**Any ×(1) from:** • Pins/markers on ruler • Marker on cylinder • Measure diameter of spheres • Mark point at centre of each sphere and use a travelling microscope to measure the separation • Fix the ruler close to spheres • Smaller diameter rod • Use of Vernier calipers (for Ben) Don't accept repeat readings			1	1		1
	(b)	(i)	$F = 9.81 \times 10^{-5}$ N (1) Use of $F = \frac{9 \times 10^9 Q_1 Q_2}{r^2}$ (1) $Q_1Q_2 = 4.36 \times 10^{-18}$ [C^2] (1)	1	1 1		3	3	3
		(ii)	$Q = (4.36 \times 10^{-18})^{1/2}$ determined (or use of 4.4×10^{-18}) = 2.09×10^{-9} C (1) Area under graph calculated: $3.2 \times 10^{-6} \times 0.65 \times 10^{-3}$ = 2.08×10^{-9} C (1) **Alternative:** Area, $Q = 2.08 \times 10^{-9}$ (1) So $QQ = (2.08 \times 10^{-9})^2 = 4.3 \times 10^{-18}$ C^2 (1)			2	2	2	2
		(iii)	$n = \frac{2.09 \times 10^{-9}}{1.6 \times 10^{-19}} = 1.31 \times 10^{10}$ electrons **ecf** on Q		1		1	1	1
			Question total	**1**	**7**	**3**	**11**	**6**	**11**

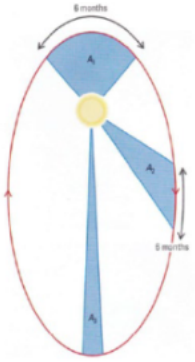
#7

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)		Potential at infinity = 0 (1) Work done on object to get to infinity, [therefore initial energy must be negative] (or equivalent) (1)	2			2		
		(ii)	I	Zero (1) No change in potential (or on same 'equipotential'). Do not accept r unchanged unless reference made to potential unchanged (1)	2			2		
			II	ΔV = (-1.79) – (-1.31) (1) Change in gravitational E_p = [-]144 M[J] (1)		2		2	2	
		(iii)		V at Moon surface calculated = -2.82 M[J] per kg (1) Loss in E_p = $m \times 0.63$ MJ (ignore –ve sign) (1) **ecf** on V at Moon surface $\frac{1}{2} mv^2 = m \times 0.63 \times 10^6$ (1) $v = (1.26 \times 10^6)^{1/2}$ [m s^{-1}] = 1.12×10^3 [m s^{-1}] (1) **Alternative:** E_p at Moon = -846 M[J] Total energy at D = -657 M[J] (1) Loss in E_p (gain in E_k) = 189 M[J] (1) $v = 1.12 \times 10^3$ [m s^{-1}] (1)	1	1 1 1		4	4	
	(b)			**Benefits - Any × (1) from:** • Easier for humans to survive on Moon if water present • Help understand origin of Earth/Moon system • To advance science • Generate interest in science/space exploration • Develop new technologies • Create jobs **Costs - Any × (1) from:** • Funding could have been used to address Earth based issues • Little current impact on society • Pollution of Moon			2	2		
				Question total	**5**	**5**	**2**	**12**	**6**	**0**

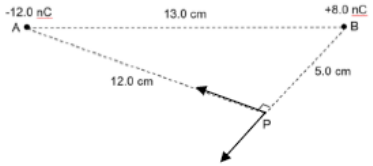
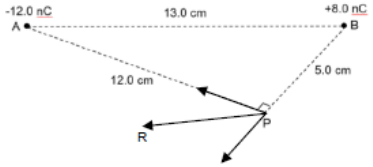
#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	(a)		**Similarity**: Both are vectors or both obey inverse square law or both have infinite range [1] **Difference:** Gravitational fields are attractive only, whereas electric fields can be attractive or repulsive. Or gravitational fields act on masses, electric fields act on charges. Accept, gravitational field is much weaker than electric field [1]	2			2		
	(b)	(i)	Substitution and answer $W = mg = 9.4 \times 10^{-14}$ [N] [1] Substitution $E = \frac{V}{d} = \frac{150}{5.0 \times 10^{-2}}$ [1] Substitution and answer $F_E = Eq = 7.2 \times 10^{-14}$ [N] [1]	1	1 1		3	2	
		(ii)	$F_E = 7.2 \times 10^{-14}$ [N]  $W = 9.4 \times 10^{-14}$ [N] F_E and W vectors correctly drawn and labelled (including directions) [1] Resultant direction of movement shown - no precision required and ecf if F_E vector drawn to the right [1] $\theta = 52.5°$ or $\alpha = 37.5°$ calculated and shown on diagram (or equivalent, e.g. bearing 217.5° stated) [1] Accept scale drawings	1	1 1		3	3	
	(c)		$F_{res} = \sqrt{(9.4 \times 10^{-14})^2 + (7.2 \times 10^{-14})^2}$ or $F_{res} = 1.18 \times 10^{-13}$ [N] seen or in (b)(ii) [1] $a \left[= \frac{F}{m} \right] = \frac{1.18 \times 10^{-13}}{9.6 \times 10^{-15}}$ or $a = 12.3$ [m s^{-2}] seen [1] Substitution and rearrangement of $x = \frac{1}{2}at^2$ i.e. $t^2 = \frac{0.04}{12.3}$ [1] $t = 0.06$ [s] Accept 0.057 [s] [1]		4		4	3	
			Question 8 total	**4**	**8**	**0**	**12**	**8**	**0**

#9

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			Areas and time periods shown correctly or described [1] $A_1 = A_2 (= A_3)$ indicated [1]  6 months	2			2		
	(b)			$\frac{mv^2}{r} = \frac{GMm}{r^2}$ [1] $v = \frac{2\pi r}{T}$ [1] Substitution and clear algebra step shown [1] **Or** $mr\omega^2 = \frac{GMm}{r^2}$ [1] $\omega = \frac{2\pi}{T}$ [1] Substitution and clear algebra step shown [1]	1	1 1		3	2	
	(c)	(i)		$\omega = \frac{2\pi}{(7.7 \times 3\,600)}$ or $2.26(7) \times 10^{-4}$ rads^{-1} seen [1] $M = \frac{(2.27 \times 10^{-4})^2 \times (9.4 \times 10^6)^3}{6.67 \times 10^{-11}}$ substitution and re-arrangement [1] $M = 6.39[8] \times 10^{23}$ k[g] [1]		3		3	3	
		(ii)	I	Substitution into $V_g = -\frac{GM}{R}$ i.e. $V_g = -\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{9.4 \times 10^6}$ [1] $V_g = -4.5(4) \times 10^6$ [J kg^{-1}] [1]	1	1		2	2	
			II	V_g at orbit of Deimos = $-\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{2.35 \times 10^7}$ $= -1.8(2) \times 10^6$ J kg^{-1}[1] $\Delta V = -1.82 + 4.54 = 2.72$ M[J kg^{-1}] [1] Energy available per kg of fuel = $0.6 \times 4.4 = 2.64$ M[J kg^{-1}] [1] Scientists should not attempt manoeuvre [1] [**ecf** based on calculations]			4	4	3	
		(iii)		One of: • g is not constant [over the distance between orbits] • g decreases as height increases • work done per metre decreases as height increases • field is not uniform		1		1		
				Question total	**4**	**7**	**4**	**15**	**10**	**0**

#10

Question			Marking details	AO1	Marks available AO2	AO3	Total	Maths	Prac
7	(a)		Electric field strength, E, is the force per unit charge [on a small positive test charge placed at the point]. (1) Electric potential, V, [at a point] is the work done per unit charge [in bringing the charge] from infinity [to that point]. (1) E- vector **and** V- scalar (both needed) (1)	3			3		
	(b)	(i)	 Both arrows seen. Ignore length of arrows. [Must be along dotted lines]	1			1		
		(ii)	 R correctly drawn and labelled [ecf]. Ignore length of arrow.		1		1		
		(iii)	E at P due to A (–12.0 nC) = 7 500 N C^{-1} (1) E at P due to B (+8.0 nC) = 28 800 N C^{-1} (1) (Deduct 1 mark for powers of 10 error) Resultant field strength at P = $(7\,500^2 + 28\,800^2)^{1/2}$ = 29 760 N C^{-1} (1) (**ecf** on both values of E) [or using horizontal and vertical components] Correct trigonometric relationship applied e.g. between R and A: $\theta = \cos^{-1}\left(\frac{7500}{29760}\right)$ = 75.4° (or 14.6° between R and B) [accept 2 sf and different ways of expressing directions] (1)		4		4	4	
	(c)	(i)	V_P due to A (–12.0 nC) =[–] 900 V V_P due to B (+ 8.0 nC) = [+] 1 440 V **Both potentials regardless of signs** (1) Correct sign convention [and addition clearly shown] (= + 540 V) (1) **Alternative** $\therefore V_P = \frac{1}{4\pi\varepsilon}\left\{\frac{-12\times10^{-9}}{12\times10^{-2}} + \frac{8\times10^{-9}}{5\times10^{-2}}\right\}$ values(1) and signs (1)		2		2	2	
		(ii)	Correct substitution into $W = q\Delta V$ i.e -1.6 × 10^{-19} (+540 – 0) (1) **Or** W = - 8.64 × 10^{-17} J seen (accept 540 eV converted into J) Hence gain in E_k = (+) 8.64 × 10^{-17} J (1) (+) can be awarded by implication	1	1		2	1	
	(d)		de Broglie $\lambda = \frac{h}{p}$ (1) Electron accelerates (or velocity or E_k increases) towards point P, **so** momentum increases (need to explain why momentum increases here) (1) So λ decreases (1) Ecf from (c) on marks 2 and 3: If $\Delta E_k < 0$ then opposite answer required.	1	1 1		3		
			Question 7 total	**6**	**10**	**0**	**16**	**7**	**0**